WHAT IS CLAIMED IS:

1. A method of forming a catalytic carbon nanostructure electrode, the method comprising:
heating an organometallic nanostructure precursor in the presence of a conductive substrate such that carbon nanostructures are grown directly on the surface of the conductive substrate by a vapor deposition process.

2. The method of claim 1, wherein the carbon nanostructures comprise carbon nanofibers doped with non-carbon atoms.

3. The method of claim 1, wherein the organometallic nanostructure precursor comprises nitrogen, wherein the carbon nanostructures comprise carbon nanonfibers doped with nitrogen atoms.

4. The method of claim 1, wherein the organometallic nanonstructure precursor comprises a metal phthalocyanine.

5. The method of claim 1, wherein the organometallic nanonstructure precursor comprises iron (II) phthalocyanine.

6. The method of claim 1, wherein the organometallic nanonstructure precursor comprises metal porphyrin.

7. The method of claim 1, wherein the organometallic nanonstructure precursor comprises a metallocene.

8. The method of claim 1, wherein heating the organometallic nanostructure precursor in the presence of the conductive substrate further comprises reacting the organometallic nanostructure precursor in an atmosphere comprising argon and hydrogen gases.

9. The method of claim 1, wherein heating of the organometallic nanostructure precursor is performed at or above a temperature at which the organometallic nanostructure precursor undergoes pyrolysis.

10. The method of claim 1, wherein the conductive substrate comprises nickel or platinum mesh.

11. The method of claim 1, wherein the carbon nanostructures comprise carbon nanotubes.

12. The method of claim 1, wherein the carbon nanostructures comprise carbon nanofibers.

13. The method of claim 1, wherein the carbon nanostructures are substantially perpendicular to the conductive substrate.

14. The method of claim 1, wherein heating the organometallic nanostructure precursor comprises selecting a pyrolysis protocol to tune at least one electrocatalyst property of the carbon nanostructures.

15. The method of claim 1, further comprising soaking at least a portion of the carbon nanostructures or the conductive substrate in an acid, and separating a carbon nanofiber film from the conductive substrate to produce three-dimensional conduits of carbon nanofiber ensembles.

16. The method of claim 1, wherein the carbon nanostructures comprise a doped carbon nanofiber film, wherein the doped carbon nanofiber film is catalytically active to solution or gas phase species.

17. A method for producing an electrode for an electrochemical device including a three dimensional catalytic ensemble of carbon nanofibers, comprising directly growing and dispersing carbonaceous materials and catalyst by vapor deposition of at least one organometallic compound.

18. A carbon nanostructure film, comprising:
a plurality of carbon nanostructures grown directly on a surface of a conductive substrate by heating an organometallic nanostructure precursor in the presence of the conductive surface.

19. The carbon nanostructure film of claim 18, wherein the carbon nanostructure film is doped with nitrogen.

20. The carbon nanostructure film of claim 18, wherein the carbon nanostructures comprise carbon nanofibers doped with non-carbon atoms.

21. The carbon nanostructure film of claim 18, wherein the organometallic nanostructure precursor comprises nitrogen, wherein the carbon nanostructures comprise carbon nanonfibers doped with nitrogen atoms.

22. The carbon nanostructure film of claim 18, wherein the organometallic nanonstructure precursor comprises a metal phthalocyanine.

23. The carbon nanostructure film of claim 18, wherein the organometallic nanonstructure precursor comprises iron (II) phthalocyanine.

24. The carbon nanostructure film of claim 18, wherein the organometallic nanonstructure precursor comprises metal porphyrin.

25. The carbon nanostructure film of claim 18, wherein the organometallic nanonstructure precursor comprises a metallocene.

26. The carbon nanostructure film of claim 18, wherein heating the organometallic nanostructure precursor in the presence of the conductive substrate further comprises reacting the organometallic nanostructure precursor in an atmosphere comprising argon and hydrogen gases.

27. The carbon nanostructure film of claim 18, wherein heating of the organometallic nanostructure precursor is performed at or above a temperature at which the organometallic nanostructure precursor undergoes pyrolysis.

28. The carbon nanostructure film of claim 18, wherein the conductive substrate comprises nickel or platinum or titanium or steel mesh.

29. The carbon nanostructure film of claim 18, wherein the carbon nanostructures comprise carbon nanotubes.

30. The carbon nanostructure film of claim 18, wherein the carbon nanostructures comprise carbon nanofibers.

31. The carbon nanostructure film of claim 18, wherein the carbon nanostructures are substantially perpendicular to the conductive substrate.

32. The carbon nanostructure film of claim 18, wherein heating the organometallic nanostructure precursor comprises selecting a pyrolysis protocol to tune at least one electrocatalyst property of the carbon nanostructures.

33. The carbon nanostructure film of claim 18, further comprising soaking at least a portion of the carbon nanostructures or the conductive substrate in an acid, and separating a carbon nanofiber film from the conductive substrate to produce three-dimensional conduits of carbon nanofiber ensembles.

34. The carbon nanostructure film of claim 18, wherein the carbon nanostructures comprise a doped carbon nanofiber film, wherein the doped carbon nanofiber film is catalytically active to solution or gas phase species.

35. The carbon nanostructure film of claim 18, wherein an overpotential necessary for the reduction of oxygen in aqueous solutions using the carbon nanostructure film is lower than on conventionally polished glassy carbon.

36. The carbon nanostructure film of claim 18, further comprising atomically dispersed nitrogen, iron, nickel, platinum, molybdenum, titanium, ruthenium, manganese, or sulfur, or alloys, oxides or mixtures thereof.

37. The carbon nanostructure film of claim 18, wherein the film is configured to be used as an electrode for catalytic reduction of oxygen.

38. A method of decomposing an oxygen containing compound, comprising:
contacting carbon nanostructures and/or a carbon nanostructure electrode with an aqueous solution comprising the oxygen containing compound.

39. The method of claim 38, wherein the carbon nanostructures and/or carbon nanostructure electrode is formed by heating an organometallic compound in the presence of a conductive substrate.

40. The method of claim 38, wherein the oxygen containing compound comprises a peroxide species.

41. The method of claim 38, wherein the oxygen containing compound comprises hydrogen peroxide.

42. The method of claim 38, wherein the oxygen containing compound comprises an alkyl peroxide.

43. The method of claim 38, wherein heterogeneous decompositions of the oxygen containing compound are catalyzed at rates comparable to MnO_2 and platinum based hydrogen peroxide decomposition catalysts.

44. The method of claim 38, further comprising preconditioning a carbon nanostructure electrode before contacting the electrode with the aqueous solution, wherein the preconditioning comprises:
contacting the electrode with a salt solution; and
cycling a potential applied to the electrode while the electrode is in contact with the salt solution, wherein cycling the potential applied to the electrode while the electrode is in contact with the salt solution increases the wettability of the electrode.

45. The method of claim 44, wherein the potential applied to the electrode is cycled over a range less than about -1 volts to about +1 volts.

46. The method of claim 38, further comprising providing electrical power using the carbon nanostructures and/or carbon nanostructure electrode.

47. The method of claim 38, further comprising sensing at least one characteristic of the aqueous solution using the carbon nanostructures and/or carbon nanostructure electrode.

48. A method of forming a catalytic carbon nanostructure electrode, the method comprising:
heating an organometallic compound in the presence of a conductive substrate.

49. A carbon nanostructure film, comprising:
a plurality of carbon nanostructures grown directly on a surface of a conductive substrate.